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Soil solution and stream water chemistry in a forested catchment I: Dynamics

Jenny L.K. Vestin, Sara H. Norström, Dan Bylund *, Per-Erik Mellander, Ulla S. Lundström

Department of Natural Sciences, Mid Sweden University, SE-85170 Sundsvall, Sweden

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Abstract

Soil solution and stream water chemistry were studied during two years in a catchment in Bispgården in central Sweden (63°07′N, 16°70′E). Soil samples and soil solution were collected in a slope at two distances (10 and 80 m) from a stream. The aims were to examine interactions between recharge (podzol) and discharge (arenosol) areas and to investigate the relations between soil solution and stream water chemistry.

The parent material was similar within the catchment, but the content of C and N were higher in the discharge area most likely due to the difference in hydrological conditions compared to the recharge area. Exchangeable cations and base saturation were higher in the discharge area than in the recharge area, which may be due to the higher content of C. The concentrations in soil solution of H, DOC, NO_3, SO_4, Al, Si, Ca and K were also higher in the discharge area compared to the recharge area which was probably caused by transportation of elements in soil and retention due to the increased content of C.

During snow melt, the concentrations in soil solution of DOC, SO_4, Al, Si, Ca and K were low due to dilution and low biological activity. The concentrations were then increasing during the seasons as an effect of biological activity and mineral weathering. NO_3 concentration in soil solution was found in higher concentrations during snow melting and was then diminishing during summer likely as a result of biological uptake.

After a dry period followed by an intensive rain in August 2003, the stream water chemistry was markedly altered for a few days. The concentrations of H, DOC SO_4, Al and Ca were increased and the concentration of Si was decreased in the stream water. It therefore appeared that the stream water mirrored the upper soil horizons in the discharge area during high flows, while reflecting the lower soil horizons and ground water during low flows.

Keywords: Discharge area; Recharge area; Stream water; Water chemistry

1. Introduction

Restricted catchments are suitable for studying and interpreting hydrological and chemical processes in ecosystems (Bishop et al., 2004; Laudon et al., 2004b; Mullholland and Hill, 1997; Stutter et al., 2006). The nutrient dynamics differs between and within catchments due to the biogeochemical processes and transport routes depending on the hydrological conditions (Stutter et al., 2006). This will result in different retention and transformation processes for the nutrients (Campbell et al., 2004; Johnson et al., 2000).

The concentrations of elements are highly influenced by biological processes and show large seasonal variations following the activity of biota. The temporal variations are normally largest in upper soil horizons and decline deeper down in the soil profile (Land and Öhlander, 1997; Lundström, 1993). The nutrient concentrations also vary with soil depth. Nutrients such as Na and Si increase in concentrations with soil depth since they mostly originate from weathering reactions, while NO_3 and K, which are intensively recirculated in biota, are found in highest concentrations in the upper horizons (Johnson et al., 2000). The nutrient concentrations in soil solution may therefore reflect both the heterogeneity and weathering of the bedrock and the activity of biota.

The discharge area is important for nutrient dynamics and stream water composition. This area may act either as a sink for the nutrients, as they can be retained by plant uptake or immobilization, or as a source of nutrients to the stream, especially during high flows like snow melting (Bishop et al., 1993; Burt, 2005; Fölster, 2000; Laudon et al., 2004b). Water may be stored in catchments during dry periods and then be

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* Corresponding author. Tel.: +46 60 148909; fax: +46 60 148820.
E-mail address: Dan.Bylund@miun.se (D. Bylund).

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released during periods of increased precipitation, i.e. storm events. Thus the stream water chemistry varies with flow (Kirchner, 2003). Bishop et al. (2004) suggested that the groundwater level increases due to the extra addition of water during these occasions and thus the water stored in the unsaturated zone is mobilized. Since the stream water chemistry is determined by the soil chemistry in the riparian zone, as this soil is the last contact before the soil solution reaches the stream, the chemistry in the runoff is a product of flow and riparian soil chemistry (Bishop et al., 2004). Langhoff et al. (2006) presented another model with three possible routes for the water to enter a stream: (i) directly through the streambed; (ii) through the streambed to the surface and then to the stream or (iii) only at the surface directly to the stream. Their results from a study in Denmark showed that the most common pathway for the water to enter the stream is through the streambed to the soil surface in combination with water directly through the streambed.

This study aims to examine the dynamics of elements and the temporal variations in element concentrations in small catchment areas in boreal forests.

The catchment studied for this purpose is situated in central Sweden and has been followed during two growing seasons. Differences in nutrient conditions between recharge and discharge areas will be investigated and the hydrological flows in a transect will be related to stream flow and stream water concentrations.

2. Materials and methods

2.1. Site description

Bispgården is located in central Sweden (63°07′N, 16°70′E) (Fig. 1) at an altitude of 258 m above sea level, which is above the highest coastline in this area. The annual precipitation is approximately 700 mm and the annual average temperature is +2 °C. The study area was located in a slope (angle 2°) towards a stream in a catchment of 50 ha with naturally regenerated 80-year-old Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*). This area has a small amount of anthropogenic deposition. The bedrock is mainly composed of granite and gneiss. The soil in the recharge area is classified as podzol and in the discharge area the soil is classified as arenosol (FAO, 1990). The study involved six plots at 10 m from the stream (arenosol) and six plots at 80 m from the stream (podzol). The plots were separated by 10–15 m each (Fig. 1). The organic horizon was on average 28 cm thick in both podzol and arenosol. The podzol had an average depth of 9 cm for E-horizons and 7 cm for the B-horizons above the C-horizons. The arenosol had an average depth of 50 cm for the A-horizons above the C-horizons. When sampling the mor layer, the living vegetation was removed and the remaining mor was divided into two parts. The upper part (O1) consisted of undegraded litter and the lower part (O2) consisted of degraded and partly degraded litter.

2.2. Soil solid

Soil samples for determination of total composition were taken from two transects including all horizons except the mor layer (E (elluvial horizon), B1 (upper illuvial horizon), C (mineral horizon) in podzol; 0–5 cm, 10–15 cm, 45–50 cm in arenosol) in September 2002. The samples for total composition were dried at 105 °C, melted with $LiBO_4$ and dissolved in HNO_3 before analysis by inductively coupled plasma mass spectrometry (ICP-MS). The analyses were performed at Analytica, Luleå, Sweden. For determination of exchangeable cations, soil content of N and C and pH, samples were taken from all transects and all horizons

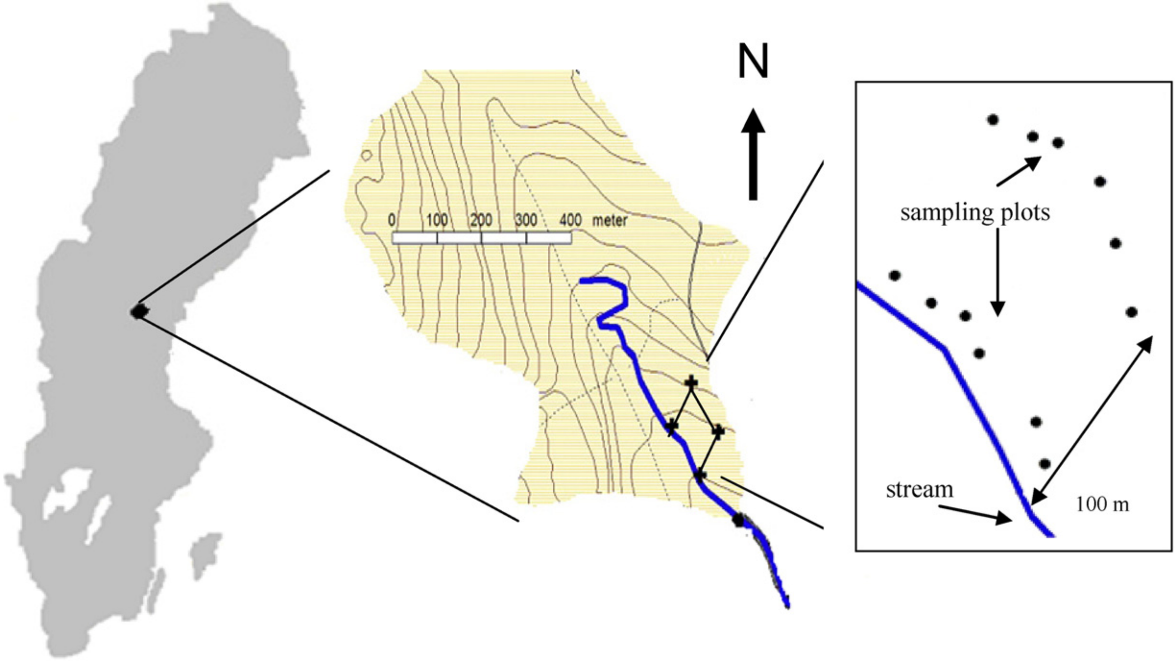

Fig. 1. The location and shape of the sampling area in Bispgården (63°07′N, 16°70′E), Sweden.